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Invention: HIGH-SPEED ACCESS FROM MOBILE STATION TO TCP/IP NETWORK

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SPECIFICATION

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HIGH-SPEED ACCESS FROM MOBILE STATION TO TCP/IP NETWORK

The invention generally relates to mobile communication networks and particularly to high-speed access from a mobile station to a data network, such as the Internet and Intranet.

Mobile communication networks generally refer to different telecommunications systems which enable personal wireless data transmission when subscribers roam within the area of the system. An example of a typical mobile communication system is the public land mobile network PLMN.

In addition to traditional speech transmission, digital mobile communication systems also provide several other services: short messages, telefax, data transmission, etc. The data transmission service, in particular, gives the opportunity to the mobile subscribers to a wireless access to nearly all fixed network data services.

The use of the TCP/IP (Transmission Control Protocol / Internet Protocol) data network, known as the Internet network, has grown exponentially in the fixed network. As is well known, the Internet network in fact consists of a large number of TCP/IP networks which are joined with one another. Private TCP/IP networks, e.g. company internal networks, are also known by the name 'Intranet'.

Internet applications are used for connecting to services in the Internet network. Before a user can connect to the Internet, he must have a contract with an Internet service provider ISP who provides access to the Internet via one or more Internet access points IAP. The ISP may be, for example, a commercial operator (like Eunet in Europe), university or a private company. The IAP is typically a server which the user can access from a conventional fixed network telephone or from a mobile station by making a modem call (or a data call) to a specific IAP access number. Typically the servers offer a modem access with the maximum rate of 56 kbits/s, or an ISDN access with a rate of 64 kbits/s.

Nowadays some Internet/Intranet servers provide bit rates of 2B (2*64 kbit/s) or even higher bit rates of n*64kbit/s for ISDN subscribers. In other words, a higher bit rate and a greater bandwidth is offered to the ISDN user by bundling two or more physical ISDN channels of 64 kbit/s into one logical link. Coordination of this bundle of physical channels is based on a

multilink-PPP protocol which is defined in IETF RFC 1990 (Internet Engineering Task Force, Request for Comments number 1990). Multilink-PPP is a method which allows to divide, sequence and recombine datagrams over several channels. The primary objective of the method was to enable the use of several parallel channels in the ISDN, but it is also applicable to any situation in which two systems are connected by several PPP (Point-to-Point Protocol) links. The point-to-point protocol (PPP) is a data encapsulating format encapsulating protocol defined in recommendations RFC 1661 and 1662 for bit-orientated synchronous links and asynchronous links.

Figure 1 illustrates a multilink PPP connection between an ISDN terminal (TE) 1 and an IAP server 2 via an ISDN network 3. There are a number (n≥2) of ISDN channels ch1-chn connected between the TE and the server 2. A PPP link is established on each channel between the corresponding PPP protocol blocks 4n and 5n, in other words, there are n independent PPP links. These independent PPP links are coordinated with multilink protocol blocks 6 and 7 so as to establish a virtual connection having a greater bandwidth than any of its subconnections (PPP links). The blocks 6 and 7 allocate the datagrams received from TCP/IP units 8 and 9 to PPP channels at the transmitting end and collect the datagrams received from the PPP channels at the receiving end and forward them to the TCP/IP units 8 and 9. There is no flow control on the connection.

High-speed data services of existing mobile communication networks, such as HSCSD (High-speed Circuit Switched Data) of the GSM mobile communication system (Global System for Mobile Communication), offer bit rates up to 64 kbit/s by means of multi-channel technology and channel coding techniques. In the multi-channel technology a mobile station is provided with a higher bit rate and greater bandwidth using several parallel traffic channels (e.g. several time slots). The ETSI (European Telecommunications Standards Institute) is also developing data rates higher than 64 kbit/s for the GSM system. This further development is based e.g. on a new modulation method which offers a higher data rate per time slot than the existing GMSK modulation, but preserves the channel spacing of 200 kHz and the TDMA frame structure. Thus it is possible to support the existing data services by a smaller number of time slots. This also allows to produce new data services having a bit rate up to 64 kbit/s per time slot or even over 64 kbit/s in the case of multi-slot constellation.

At the moment third-generation mobile communication systems are under development. These include the Universal Mobile Communication System (UMTS) and Future Public Land Mobile Telecommunication System (FPLMTS) which has been renamed IMT 2000 (International Mobile Communication 2000). The UMTS is being standardised at the ETSI (European Telecommunication Standards Institute), whereas the ITU (International Telecommunication Union) standardises the IMT 2000 system. These future systems have very similar basic features. In the third-generation systems the data rate will probably be 2 Mbit/s at the radio interface, but in any case many times higher than 64 kbit/s.

Mobile subscribers also have access to the Internet/Intranet network through the data transmission services of the mobile communication systems, either directly from the mobile communication network (the IAP server is connected directly to an interworking function IWF of the mobile services switching centre MSC, e.g. with a dedicated circuit of 2 Mbit/s) or via the ISDN (there is an ISDN network between the MSC/IWF and the IAP server). Figure 2 illustrates access to the Internet via the ISDN network when one link is used (data rate at most 64 kbit/s). The uppermost protocol layers are TCP/IP and PPP in the mobile station MS and IAP server 2. Below these there is a GSM traffic channel between the MS and the IWF and an ISDN channel between the IWF and the IAP server 2. The GSM traffic channel is configured as a non-transparent traffic channel on which a radio link protocol L2R/RLP and rate adaptations RA are used. The RLP is a frame-structured, balanced (HDLC type) data transmission protocol in which error correction is based on retransmission of corrupted frames at the request of the receiving party. Because of the RLP it is also necessary to use an ITU-T V.120 transmission protocol comprising a flow control mechanism on the ISDN channel.

When the above-mentioned data rates of over 64 kbit/s are introduced into mobile communication networks, it is also necessary to implement the support of the multilink PPP protocol in the mobile communication network so that high-speed (n*64 kbit/s) access to the Internet/Intranet networks could also be offered to mobile subscribers.

An object of the invention is to provide a high-speed access supporting a multilink PPP protocol to data networks, such as TCP/IP networks.

This is achieved with a mobile communication system according to claim 1, a mobile station according to claim 15, an interworking function according to claim 21, and a method according to claim 25.

According to the basic principles of the invention, a mobile network subleg between a mobile station and an interworking function, such as the IWF or another network element, is allocated to as many subchannels or sub-traffic streams as there are channels (e.g. time slots of 64 kbit/s) on another subleg between the IWF and the access point of another telecommunications network, such as the IAP server. Each channel of the fixed network leg as well as the PPP link payload carried by the channel are adapted to the mobile network subchannel or substream allocated to the channel so that the PPP payload is transferred as such over the whole point-to-point connection between the multilink PPP protocol functions located in the mobile station and IAP server. This allows to avoid placing of PPP and multilink PPP protocols in the interworking function IWF or in any other network element in the mobile communication network.

There are several ways of dividing a mobile network subleg into subchannels or substreams. Since the radio connection is liable to interference, a dedicated link access control protocol LAC, in which error correction is based on retransmission, is usually used between the mobile station and the interworking function. In some mobile communication systems this protocol is called a radio link protocol RLP.

In an embodiment of the invention there is a separate LAC link and a physically separate traffic channel or traffic stream for each PPP link (and PPP subchannel) between the mobile station and the interworking function.

In another embodiment of the invention there is a separate LAC protocol link for each PPP link and one common broadband traffic channel for all PPP links between the mobile station and the interworking function. The mobile station and interworking function multiplex PPP links into this broadband traffic channel. Multiplexing may be carried out e.g. by multiplexing the frames of each separate LAC protocol link into said broadband traffic channel.

In a yet another embodiment of the invention there is one common LAC protocol link for all PPP links between the mobile station and the interworking function, and the PPP subchannels are multiplexed inside the LAC protocol link.

In the following, preferred embodiments of the invention will be described with reference to the accompanying drawings, in which

Figure 1 illustrates a multilink PPP connection in an ISDN network,

Figure 2 illustrates a single-link PPP connection to the Internet/Intranet network,

Figure 3 illustrates a GSM mobile communication system,

Figure 4 illustrates protocols and functions according to the GSM recommendations in non-transparent bearer services,

Figure 5 illustrates a protocol structure of a non-transparent HSCSD connection according to the GSM recommendations,

Figure 6 illustrates a connection supporting the multilink PPP between a mobile station MS and an IAP server,

Figures 7, 8 and 9 illustrate multilink PPP connections according to different embodiments of the invention,

Figures 10 and 11 illustrate multiplexing of PPP links into RLP frames, and

Figures 12, 13, 14 and 15 illustrate multilink PPP connections according to different embodiments of the invention in third-generation mobile communication systems.

The present invention is applicable to all digital wireless telecommunications systems, such as cellular systems, WLL (Wireless Local Loop) and RLL (Radio Local Loop) networks, satellite-based mobile communication systems, etc. Here the term mobile communication system (or network) generally refers to all wireless telecommunications systems. There are several multiple access modulation techniques which facilitate traffic involving a large number of mobile users. These techniques include time division multiple access (TDMA), code division multiple access (CDMA) and frequency division multiple access (FDMA). The physical concept of the traffic channel varies in different multiple access methods, being primarily defined by means of a time slot in TDMA systems, by means of a spreading code in CDMA systems, by means of a radio channel in FDMA systems, by means of a combination of these, etc. In modern mobile communication systems it is possible to allocate a set of two or more basic-rate traffic channels (sub-channels), i.e. a high-speed traffic channel, to a mobile station for high-speed data transmission. Here the term traffic channel refers both to a single basic-rate traffic channel and to a high-speed traffic channel consisting of two or

more basic-rate traffic channels. The basic idea of the present invention is independent of the type of the traffic channel and the multiple access method used.

The present invention is particularly suitable for data transmission applications in the Pan-European digital mobile communication system GSM (Global System for Mobile Communications) and in other GSM-based systems, such as DSC1800 (Digital Communication System), the US digital cellular system PCS (Personal Communication System) and GPRS (General Packet Radio Service), and in WLL systems which are based on the above-mentioned systems. The invention will be described below using the GSM mobile communication system as an example. The structure and function of the GSM system are very familiar to a person skilled in the art and they are defined in the GSM specifications of ETSI (European Telecommunications Standards Institute). Reference is also made to *GSM System for Mobile Communication*, M. Mouly and M. Pautet, Palaiseau, France, 1992; ISBN: 2-9507190-0-7.

The basic structure of the GSM system is illustrated in Figure 3. The GSM system consists of two parts: a base station system BSS and a network subsystem NSS. The BSS and mobile stations MS communicate over radio connections. In the base station system BSS each cell is served by a base transceiver station BTS. A number of base transceiver stations are connected to a base station controller BSC, which controls the radio frequencies and channels the BTS uses. The BSCs are connected to a mobile services switching centre MSC. Certain MSCs are connected to other telecommunications networks, such as the public switched telephone network PSTN, and comprise gateway functions for calls transmitted to those networks and calls arriving from those networks. These MSCs are known as gateway MSCs (GMSC). There are also at least two databases, a home location register HLR and a visitor location register VLR.

The services of mobile communication systems are generally classified into tele-services and bearer services. A bearer service is a telecommunications service which provides signal transmission between the user interfaces and the network interfaces. An example of bearer services is a modem service. In the tele-service terminal services are also offered by the network. Important tele-services include speech, telefax and videotex services. The bearer services are usually subdivided into groups, such as asynchronous

bearer services and synchronous bearer services, on the basis of a certain feature. In the case of the asynchronous bearer service the transmitting terminal and the receiving terminal are able to maintain their synchronization only for each single character to be transmitted. In the case of the synchronous bearer service the transmitting terminal and the receiving terminal are synchronized with each other for the whole duration of data transmission. Each such bearer service group comprises a number of bearer services, such as a transparent service and a non-transparent service. In the transparent service the data to be transmitted is unstructured and transmission errors are corrected only by means of channel coding. In the non-transparent service the data to be transmitted is structured into protocol data units (PDU) and transmission errors are corrected using automatic retransmission protocols (in addition to channel coding).

The mobile communication system comprises adaptation functions for adapting the internal data connection of the mobile network to the protocols used by the terminals and other telecommunications networks. The adaptation functions typically include a terminal adaptation function TAF on the interface between the mobile station and the data terminal connected to the mobile station and an interworking function IWF on the interface between the mobile communication network and another telecommunications network, typically in association with the mobile services switching centre. Usually the mobile services switching centre comprises various kinds of adapter equipment pools for supporting different data services and data protocols, such as a modem pool which comprises modems and telefax adapters for modem and telefax services, UDI/RDI rate adapter pool, etc. Referring to Figure 3, in the GSM system a data connection is established between the terminal adaptation function TAF 31 of the mobile station MS and the interworking function IWF 41 in the mobile communication network. In non-transparent data services the GSM connection also uses a radio link protocol RLP. The TAF adapts the data terminal equipment DTE connected to the mobile station MS to said GSM data connection, which is established over a physical connection using one or more traffic channels. The IWF connects the GSM data connection to another network, such as GSM, ISDN or PSTN, or directly to the IAP server, for example.

Figure 4 illustrates protocols and functions which are needed in the IWF (either in the MSC or in a WLL-specific network element) for non-

transparent bearer services. The non-transparent circuit-switched connection over the GSM traffic channel between the terminal adaptation function TAF and the interworking function IWF comprises several protocol layers which are common to all these services. These include various rate adaptation functions RA, such as RA1' between the terminal adaptation function TAF and the CCU unit (Channel Codec Unit) located in the base station system BSS, RA1 between the CCU unit and the interworking function IWF, RAA between the CCU unit and a transcoder unit TRAU located remote from the base station, and RA2 between the transcoder unit TRAU and the interworking function IWF. Rate adaptation functions RA are defined in GSM recommendations 04.21 and 08.20. Traffic between the CCU unit and the transcoder unit TRAU is defined in the GSM recommendation 08.60. At the radio interface the RA1' rate-adapted information has also been channel-coded according to the GSM recommendation 5.03, which is illustrated by the FEC blocks in the mobile station MS and CCU unit. The IWF and TAF also comprise protocols of upper layers which are service-specific. In an asynchronous non-transparent bearer service the IWF needs L2R (Layer 2 Relay) and RLP (Radio Link Protocol) protocols and a modem or a rate adaptation function in the direction towards the fixed network. The L2R functionality for non-transparent character-oriented protocols is defined e.g. in the GSM recommendation 07.02. The RLP protocol is defined in the GSM recommendation 04.22. The RLP is a frame-structured, balanced (HDLC type) data transmission protocol in which error correction is based on retransmission of corrupted frames at the request of the receiving party. The interface between the IWF and e.g. an audiomodem MODEM is in accordance with CCITT V.24. In Figure 5 this interface is indicated with symbol L2. This non-transparent configuration is also used for access to the Internet network.

In the HSCSD concept of the GSM system a high-speed data signal is splitted into separate data flows which are then transmitted via N subchannels (N traffic channel time slots) on the radio interface. After the data flows have been splitted, they are carried on subchannels as if they were independent of one another until they are combined again in the IWF or MS. However, logically these N sub-traffic channels belong to the same HSCSD connection, i.e. they form one HSCSD traffic channel. According to the GSM recommendations, data flows are splitted and combined in a modified RLP, which is thus common to all subchannels. Below this common RLP each

subchannel has the same protocol stack RA1'-FEC-FEC-RA1'-RAA-RAA-RA2-RA2-RA1 between the MS/TAF and the MSC/IWF, the protocol stack being illustrated for one traffic channel in Figure 4. The protocol structure of an HSCSD traffic channel according to the GSM recommendations is illustrated in Figure 5. Thus the HSCSD traffic channel according to the GSM recommendations will still use the common RLP for different subchannels, even though the bit rate of an individual subchannel may be up to 64 kbits/s.

As was stated above, solutions are being developed for the GSM system which enable data rates up to 64 kbits/s per time slot or data rates exceeding 64 kbits/s in the multi-slot constellation (HSCSD). However, this development work does not affect the protocol structures described above with reference to Figure 5, but only the bit rate of the traffic channel. Thus the HSCSD traffic channel according to the GSM recommendations will still use the common RLP for different subchannels, even though the bit rate of an individual subchannel may be up to 64 kbits/s and the total rate of the HSCSD traffic channel n*64 kbit/s.

Such a GSM traffic channel of n*64 kbit/s will also enable high-speed access to the TCP/IP network described above provided that the mobile communication network supports this.

One possible way of implementing the multilink PPP in mobile communication networks which was studied by the inventor is illustrated in Figure 6. This solution is a rather straightforward combination of the prior art solutions illustrated in Figures 1 and 2. The MS-IWF connection (a traffic channel of n*64 kbit/s) uses a radio link protocol RLP (or a corresponding link access protocol LAC) and plain PPP protocol above the RLP (or LAC) for one traffic channel of 64 kbit/s as in Figure 2. The leg between the IWF and the IAP server which comprises two or more time slots of 64 kbit/s uses the multilink PPP protocol and adaptation of the PPP/multilink PPP protocols in the IWF in the same way as the leg between the TE and the server 2 in Figure 1. To be more precise, a multilink unit 6 and PPP units 4 have been added to the IWF so that the IWF functions towards the server 2 like the ISDN terminal TE. Since an RLP is used on the radio path and the PPP protocol does not comprise flow control mechanisms, there must be another protocol 60 and 61 comprising a flow control mechanism (such as ITU-T V.120) below the PPP protocol 4 and 5 between the IWF and the IAP server, which is currently the case when one channel of 64 kbit/s is used as in Figure 2. Even though the

concept according to Figure 6 is functional, significant problems are related to it according to the inventor, and thus it is not sensible to use it in practice. The interworking function IWF has to support two new protocols, i.e. a plain PPP protocol (towards the MS) and a multilink PPP protocol (towards the IAP server), and to adapt these protocols. The existing IWFs of the mobile communication networks do not support these protocols since they are Internet protocols between the client and the server. Furthermore, since an additional flow control protocol is needed below the PPP, the total number of protocol functions increases considerably in the IWF. As a result of this 1) the complexity of the IWF increases, 2) the processing load in the IWF increases, 3) the memory consumption in the IWF increases, and 4) the mobile communication network becomes dependent on the development of Internet protocols.

Preferred embodiments of the present invention will be described in the following with reference to Figures 8 to 11. According to the basic principles of the invention, a mobile network traffic channel is allocated to as many subchannels or sub-traffic streams as there are time slots (channels) of 64 kbit/s on the subleg between the IWF and the IAP server. Each time slot of 64 kbit/s of a fixed network connection or channel as well as the PPP link payload are adjusted to the mobile network subchannel or substream allocated to it so that the PPP payload is transferred as such over the whole point-to-point connection between the multilink PPP protocol functions located in the mobile station and IAP server. This allows to avoid placing of PPP and multilink PPP protocols in the interworking function IWF. Furthermore, in the mobile station MS the multilink PPP protocol is typically located in a separate integrated terminal part TE, which in practice is usually a personal computer PC. Implementation of the multilink PPP protocol for a data terminal TE does already exist since the ISDN networks support the use of several connections of 64 kbit/s and the Internet access servers which are connected to the ISDN support the multilink PPP connection, as was already described with reference to Figure 1. A mobile station (MS) supporting the present invention can be implemented in a simple manner by connecting such a TE to or by integrating it into a mobile terminal MT which comprises radio parts and other functions required by the mobile communication network, including the allocation of a traffic channel to subchannels or substreams according to the invention. In this application the term mobile station MS generally refers both to the case in

which the TE and MT are integrated into one unit and to the case in which the TE is a separate unit which is connected to the MT.

There are several ways of dividing a mobile network traffic channel into subchannels or substreams. Some of these will be described in greater detail in the following.

One way of establishing n PPP subchannels or PPP substreams through the mobile communication network is physical separation using separate traffic channels or substreams of the underlying mobile communication network. One or more physical substreams or subchannels (e.g. 2 * 28.8 kbit/s enhanced GSM data rate channels) may form one PPP substream or one PPP subchannel. A separate L2R/RLP (or more generally a link access control protocol LAC) is established for each PPP substream or PPP subchannel. This embodiment is illustrated in Figure 7.

The TE part of the mobile station MS comprises a TCP/IP protocol unit 8, multilink protocol unit 6 and n PPP protocol units $4_1 \ldots 4_n$, which implement a multilink PPP protocol according to RFC1990, for example, towards the server 2. Thus the basic structure of the TE may be very similar to that of the fixed network TE illustrated in Figure 1. The server 2 comprises a TCP/IP protocol unit 9, multilink protocol 7 and n PPP protocol units $5_1 \ldots 5_n$, which implement a multilink PPP protocol according to RFC1990, for example. Furthermore, there is one V.120 unit $61_1 \ldots 61_n$ for each PPP link. Thus the server 2 can be implemented according to the same principles as in Figures 1 and 2. Consequently, n PPP links $PPP_1 \ldots PPP_n$ are transferred between the TE and the server on the multilink PPP protocol layer.

Each PPP link PPP_1-PPP_n from the terminal TE is thus connected to a separate L2R/RLP unit 71_1-71_n in the MT part of the mobile station MS. Each L2R/RLP unit 71 is connected to a separate rate adaptation unit $RA73_1 \ldots 73_n$. Each rate adaptation unit 73_1-73_n has a corresponding rate adaptation unit 74_1-74_n in the interworking function IWF in the mobile services switching centre MSC. Between each rate adaptation pair 73 and 74 there is a rate-adapted data connection according to the GSM recommendations, which may consist of one or more GSM subchannels or substreams (cf. one GSM traffic channel or HSCD traffic channel). In the IWF each rate adaptation unit 74_1-74_n is connected to a respective L2R/RLP unit $72_1 \ldots 72_n$. A separate RLP link, or generally an LAC link, is established between each pair 71 and 72 of the L2R/RLP units. Each RLP link forms a kind of subchannel on which the

corresponding payload of the PPP link can be transmitted. These subchannels according to the invention are called PPP subchannels, and the PPP data streams carried over them are called PPP substreams. In addition, in the IWF each L2R/RLP unit 72_1-72_n is connected to a fixed network transmission protocol unit $60_1 \ldots 60_n$ which supports the V.120 protocol or another protocol comprising flow control. Each unit 72 feeds the same PPP payload data that the respective unit 71 received from the terminal T in the mobile station MS into the respective unit 60. Each protocol unit 60_1-60_n establishes a V.120 link with the respective protocol unit 61_1-61_n via the channels ch_1-ch_n. The same PPP signals PPP_1-PPP_n that occur between the units 71_1-71_n and 4_1-4_n in the mobile station MS occur between the units 61_1 and 61_n and the PPP protocol units 5_1-5_n. In the opposite transmission direction traffic is implemented in the same way. Thus it is possible to establish a connection through the mobile communication system which transmits the signals of the multilink PPP protocol "transparently" through the mobile communication network without the interworking function IWF needing to support the PPP protocol or the multilink PPP protocol or needing to adapt the protocols. The use of a separate RLP unit in the IWF and MS does not in practice increase the processing load because each RLP unit functions at a rate which is only part of the rate of a normal common RLP unit. It should, however, be noted that the present invention differs significantly from the established practice and present GSM recommendations in that it uses several separate RLP protocol units instead of one common RLP unit, which was described with reference to Figure 5.

Another way of implementing allocation to PPP subchannels is physical separation by means of multiplexing in one broadband (> 64 kbit/s) traffic channel, e.g. in a TDMA/CDMA or CDMA channel. The broadband channel is allocated to subchannels using the frame structure of the traffic channel, e.g. dedicated transmission frame bits. This embodiment also uses a separate L2R/RLP link (or LAC link) for each PPP link. Thus one possible way of implementing multiplexing is to provide separate RLP/L2R links with an identifier in the frame structure and to transfer them mixed together in one broadband channel. This embodiment will be described in greater detail with reference to Figure 8.

In Figure 8 the server 2 and the terminal part TE of the mobile station MS may be similar to those illustrated in Figure 7. The MT part of the mobile station MS comprises a separate L2R/RLP unit (or e.g. an LAC unit)

$81_1 \ldots 81_n$ similar to units $71_1 \ldots 71_n$ in the MT part in Figure 7. Each L2R/RLP unit 81_1-81_n is connected to its respective I/O port in a multiplexing and demultiplexing unit 83. The multiplexing and demultiplexing unit 83 multiplexes the RLP frames received from the units 81_1-81_n into one signal which is supplied to a rate adaptation unit 85. Even though units 83 and 85 are illustrated as separate units in Figure 8, they may also be integrated into the same unit. In this embodiment of the invention the multiplexer 83 multiplexes the RLP frames received from the L2R/RLP units 81_1-81_n into transmission frames to be transmitted on a broadband traffic channel, e.g. the RLP frames of each PPP link into certain bit locations in the transmission frame. In the GSM system, for example, V.110 frames are transmitted between the RA1' and RA 1 adaptations. Certain data bits can be allocated to each PPP link in these V.110 frames. The RA unit 85 establishes a rate-adapted data connection according to the GSM recommendations with another RA unit 86 which is located in the interworking function IWF in the mobile services switching centre MSC via a broadband traffic channel. The broadband traffic channel may be e.g. a HSCSD traffic channel or a broadband traffic channel of a third-generation mobile communication system. The RA unit 86 supplies the multiplexed signal received from the mobile station MS to a multiplexing and demultiplexing unit 84 which demultiplexes the RLP frames of each PPP link apart and supplies them to the corresponding L2R/RLP units (or LAC units) 82_1-82_n. The units 82_1-82_n separate the PPP payload from the RLP frames and supply them to the fixed network protocol units 60_1-60_n. The units 60 are similar to those illustrated in Figure 7, and the further connection to the server 2 also functions in the same way. Traffic is implemented in the same way in the opposite transmission direction.

Thus in Figure 8 n subchannels are also established between the multiplexers 83 and 84, and an L2R/RLP link is established on each of the subchannels. These subchannels are PPP subchannels according to the invention via which PPP data can be transmitted through the mobile communication network without functions related to the PPP protocol or the multilink PPP protocol being necessary in the IWF.

A yet another way of implementing a multilink PPP over the mobile communication network is to use one L2R/RLP link (or LAC link) for transmitting all PPP links via the PPP subchannels of the invention between the MS and the IWF. These subchannels are established by performing PPP

subchanneling inside this L2R/RLP link. The underlying traffic channel may consist of only one channel which has a sufficiently high bit rate (e.g. a third-generation mobile communication network comprising a WCDMA or TDMA/CDMA channel), or the traffic channel may consist of several subchannels/substreams (like in the HSCSD configuration of the GSM system, for example). This embodiment will be described by means of an example with reference to Figure 9.

In Figure 9 the structure and function of the server 2 and the terminal part TE of the mobile station MS are similar to those in Figures 7 and 8. PPP links PPP_1-PPP_n from the terminal T are supplied to a multiplexing and demultiplexing unit 91 in the MT part. The multiplexing and demultiplexing unit 91 multiplexes the data of the PPP links into one signal which is supplied to a common L2R/RLP unit (or LAC unit) 93, where the multiplexed data are inserted into RLP frames or into an LAC data field. Thus all PPP links PPP_1-PPP_n are multiplexed into the frames of one RLP link. In practice, the functions of the units 91 and 93 can also be integrated so that the L2R/RLP unit carries out multiplexing (and demultiplexing) as it forms (drops) RLP links. The L2R/RLP unit 93 feeds the RLP frames into the rate adaptation unit 85. The rate adaptation unit 85 has a rate-adapted data connection (e.g. in accordance with the GSM recommendations) with another RA unit 86 which is located in the interworking function IWF. The RA unit 86 feeds the RLP frames into an L2R/RLP unit 94. The unit 94 separates the multiplexed data from the RLP frames and supplies the data to a multiplexing and demultiplexing unit 92. The unit 92 demultiplexes the data related to each PPP link PPP_1-PPP_n apart and supplies the data to the fixed network protocol units 60_1-60_n. The units 60 as well as the further connections to the server 2 are similar to those illustrated in Figures 7 and 8. Traffic is implemented in the same way in the opposite transmission direction.

In the embodiment of Figure 9 n PPP subchannels which are multiplexed into RLP frames (or LAC frames) are established between the multiplexing and demultiplexing units 91 and 94. Thus the multilink PPP connection can be transferred "transparently" through the mobile communication network without functions according to the PPP protocol or the multilink PPP protocol or adaptations between them being necessary in the IWF.

PPP links PPP_1-PPP_n can be multiplexed in to an RLP link (or LAC link) in several ways. Figure 10 illustrates one such way in which each RLP/LAC link carries information from each PPP link. Let us assume that there are two PPP links, i.e. n = 2. In the data field of each RLP/LAC frame PPP payload (PPP1 DATA) from the first PPP link PPP_1 is inserted into certain bit locations and payload (PPP2 DATA) from the second PPP link PPP_2 into other bit locations.

Figure 11 illustrates a case in which each RLP/LAC frame carries information from only one PPP link at a time. Let us again assume that two PPP links are used. The payload (PPP1 DATA) from the first PPP link PPP_1 and a link identifier LINK ID which indicates to which PPP link the data in said RLP/LAC are related are inserted into the data field of every other RLP/LAC frame. Correspondingly, the payload (PPP2 DATA) from the second PPP link PPP_2 and the link identifier LINK ID are inserted into every other RPL/LAC frame. The link identifier may be for example a numerical value at the beginning of a data field, as in Figure 11. The multiplexing principles of Figures 10 and 11 are applicable to an arbitrary number of PPP links.

The invention has been described above in a second-generation (2G) mobile communication system GSM. The architectures of different mobile communication systems may differ from that of the GSM system, but the basic principles of the present invention as well as the methods of implementation described above in connection with the GSM system are applicable to any network architecture. In the following the invention will be illustrated in third-generation (3G) mobile communication systems.

As an example of a third-generation network we use the UMTS network, which is still under development. It should be noted that the detailed structure of the UMTS access network is not relevant to the invention. According to the simplest approach, the UMTS is an access network whose functions are strictly limited to radio access functions. Thus it mainly comprises functions for the control of radio resources (handover, paging) and control of bearer services (control of the radio network service). Complex functions, such as registers, registration functions, location and mobility management, are located in a separate network subsystem NSS or in the core network. The NSS or the core network may be e.g. a GSM infrastructure.

Transition to the use of third-generation mobile communication systems will happen in stages. At the initial stage third-generation radio

access networks will be used in the network infrastructure of the second-generation mobile communication systems. Such a "hybrid system" is illustrated in Figures 12 and 15. A third-generation radio access network consisting of a radio network controller RNC (and an interworking unit IWU) and base stations BS, for example, is connected to a second-generation mobile services switching centre.

Since the third-generation radio access network is not designed to be compatible with the second-generation (2G) infrastructure (MSC/IWF), it is clear that such a mixed architecture requires an interworking function between the networks, which is usually described as an interworking unit (IWU). It is a general requirement that no changes are allowed in the 2G system (in the mobile services switching centre MSC), and thus e.g. the interface between the GSM MSC and the IWU must be a pure A interface. The IWU must perform all conversions between the second-generation and the third-generation formats and functions.

Figure 12 illustrates a connection supporting the multilink PPP between the mobile station MS and the IAP server in a 2G/3G hybrid network. The TE part of the mobile station may be exactly the same as that illustrated in Figures 8 and 9, for example. The MT part can also be implemented according to the same principles that were described in connection with Figures 8 and 9. In other words, the MT part comprises a unit 120 which establishes the LAC and/or RLP protocols and multiplexes the PPP signals PPP_1-PPP_n into a high-speed mobile network traffic channel as well as demultiplexes them in the opposite direction. The RLC protocol (Radio Link Control) is used on a radio link between the mobile station MS and the RLC unit 122 in the radio network controller RNC. The IWU between the RNC and the MSC/IWF comprises the adaptation functions needed between the 3G radio access network traffic channel and the A interface of the 2G mobile services switching centre. The MSC/IWF comprises a unit 121 which includes an LAC protocol unit, which demultiplexes the signals of each PPP link from the mobile network traffic channel and feeds them into the corresponding fixed network protocol units 60_1-60_n (typically via rate adaptation functions RA). The units 60 are similar to those illustrated e.g. in Figure 8, and the further connection to the server 2 also functions in the same way. Thus in Figure 12 n subchannels are established inside the broadband traffic channel of the mobile communication system between the multiplexers 120 and 121, and an LAC link is established

on each of these subchannels according to the principles of the embodiment illustrated in Figure 8 or the subchannels are multiplexed into the LAC frames of one LAC link according to the principles of the embodiment illustrated in Figure 9. Thus the multilink PPP connection can be transferred "transparently" through the mobile communication network without the IWF or any other mobile network element needing to have functions related to the PPP rotocol and the multilink PPP protocol or adaptations between them.

Figure 13 illustrates a connection supporting the multilink PPP between the mobile station MS and the IAP server in a pure 3G network architecture. In Figure 13 the third-generation (3G) radio access network is similar to that illustrated in Figure 12. In other words, in Figure 13 the MS BTS and RNC may be similar to those illustrated in Figure 12. However, in Figure 13 the network comprises is a third-generation (3G) mobile services switching centre MSC/IWF which is designed to be compatible with the 3G radio access network. For this reason no separate interworking function IWU is needed between the radio network controller RNC and the 3G MSC like in Figure 12, but the broadband 3G traffic channel extends up to the MSC. The 3G MSC may be provided with an LAC and multiplexing unit 121 similar to the 2G MSC of Figure 12. Thus in Figure 13 n subchannels are also established between the multiplexers 120 and 121, and an LAC link is established on each of these subchannels according to the principles of the embodiment illustrated in Figure 8 or the subchannels are multiplexed into the LAC frames of one LAC link according to the principles of the embodiment illustrated in Figure 9. The unit 121 demultiplexes the data related to each PPP link PPP_1-PPP_n apart and feeds the data to the fixed network protocol units 60_1-60_n. The units 60 as well as the further connections to the server 2 are similar to those illustrated in Figure 12, for example. Traffic is implemented in the same way in the opposite direction. Thus the multilink PPP connection can be transferred "transparently" through the mobile communication network without functions related to the PPP protocol or the multilink PPP protocol or adaptations between them ibeing necessary in the IWF or in any other mobile network element.

The final third-generation (3G) embodiment may also have an architecture with a circuit-switched data connection between the MS and the MSC/IWF without an RLP/LAC/LLC protocol. In this architecture the retransmitting protocol, i.e. either a plain RLC or both the RLC and the LAC, is

at the radio interface between the MS and the RNC. Such a network architecture is illustrated in Figures 14 and 15.

Figure 14 illustrates implementation of the present invention in a pure 3G mobile communication system where the LAC and RLC function between the MS and the RNC. The mobile station MS is similar to that illustrated in Figures 12 and 13. The radio network controller RNC comprises a unit 140 which comprises the RLC function of Figures 12 and 13 and also an LAC function transferred from the unit 121 of Figures 12 and 13. Thus LAC and RLC links are formed between the units 120 and 140. There may also be only an RLC protocol between the MS and the RNC.

The PPP subchannels according to the invention can be established between the MS and the RNC in the same way as was described above for the LAC protocol. The subchannels in question run inside a broadband 3G channel between the RNC and the 3G MSC/IWF. The MSC/IWF comprises a multiplexing unit 141 which is similar to the unit 121 illustrated in Figure 12 and 13, except that it does not comprise the LAC function. Again, n PPP subchannels are formed between the multiplexing and demultiplexing units 120 and 141. The unit 141 demultiplexes the data related to each PPP link from the PPP subchannels of the 3G traffic channel and supplied the data to the fixed network protocol units 60_1-60_n. The units 60 as well as the further connections to the server 2 are similar to those illustrated in Figure 12. Traffic is implemented in the same way in the opposite direction. Thus the multilink PPP connection can be transferred "transparently" through the mobile communication network without functions related to the PPP protocol or the multilink PPP protocol or adaptations between them being necessary in the IWF or in any other mobile network element.

Figure 15 illustrates a connection supporting the multilink PPP according to the invention between the mobile station and the IAP server when the mobile communication network is a 2G/3G hybrid network and the retransmitting protocol is between the MS and the RNC. The mobile station MS, base station BTS and radio network controller RNC may be similar to those illustrated in Figure 14. However, an interworking unit IWU is needed between the radio network controller RNC and the second-generation MSC. The IWU performs the necessary adaptations between the broadband 3G traffic channel and the A interface of the GSM system, for example. In the case of Figure 15 the IWU also comprises a multiplexing and demultiplexing

unit 150 which may be substantially similar to the demultiplexer 141 in Figure 14. In the embodiment of Figure 15 there are n traffic channels of 64 kbit/s at the A interface between the IWU and the MSC. According to the invention, n PPP subchannels are formed between the multiplexing units 120 and 150. The multiplexing unit 150 demultiplexes the data related to each PPP link PPP_1-PPP_n from the PPP subchannels of the broadband 3G traffic channel and supplies the data to corresponding traffic channels of 64 kbit/s at the A interface. The MSC/IWF comprises the rate adaptation 150 required by the GSM system for each traffic channel. PPP signals are fed from the rate adaptations 151_1-151_n to the fixed network protocol units 60_1-60_n. The units 60 as well as the further connections to the server 2 may be similar to those illustrated in Figure 12. Traffic is implemented in the same way in the opposite transmission direction. According to the invention, n PPP subchannels are consequently established between the MS and the MSC/IWF, too. Thus the multilink PPP connection can be transferred "transparently" through the mobile communication network without functions related to the PPP protocol or the multilink PPP protocol or adaptations between them in the IWF or in any other mobile network element.

It is to be understood that the mobile communication network architectures and location or distribution of the functions according to the invention to different network elements may differ considerably from the architectures and configurations described above, without deviating from the inventive concept. Thus the term interworking function has to be understood broadly in this application, i.e. it refers to any interworking function, such as IWU or IWF, or to any network element, e.g. RNC, in which it is advantageous to implement the functions of the invention in a given network architecture. The invention has been described above by means of preferred embodiments. It should be noted that there are alternative solutions and variations which are obvious to a person skilled in the art and can be implemented without deviating from the scope and spirit of the appended claims.